Rating of tinted ophthalmic lenses

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ABSTRACT

This study aims at establishing the relationship between the spectral transmission characteristics of tinted ophthalmic lenses and the visual percept of the observer looking through. We hypothesise that the rating of tinted lenses originates from what the observer sees rather than what the glass looks like. We develop a model for colour acceptance by calculating the colour distortions for a collection of coloured surfaces that are representative of the real environment using the spectral reflectance of the surfaces and the spectral transmittance of the lens. Then we apply the model to a collection of real tinted ophthalmic lenses and derive statistical indices that describes the global colour distortion induced by each lens. Preliminary results show a significant agreement between the subjective rating and the objective colour distortion index. We conclude that our model allows to predict the acceptance/rejection judgement of observers for a tinted ophthalmic lens of known spectral transmittance.

Keywords: Colour vision, Ophthalmic lens

1. INTRODUCTION

Illumination varies greatly in the environment. Although the visual system adapts to about 10 decades of illumination and from about 2 000 K to 10 000 K colour temperature, adaptation to the light environment can be facilitated by wearing tinted lenses. A large choice of tinted ophthalmic lenses is proposed to customers who make a buying decision on the basis of subjective criteria. The choice of the tinted lens is very often left to the wearer. However it is restricted within the range of glasses proposed by the manufacturer of spectacles which in turn is under the control of dye chemistry. We have noticed that already a slight colour change can cause tinted spectacles to be rejected. The question arises whether a tinted ophthalmic lens could be designed to better meet the wearer's needs and satisfaction.

We hypothesise that the acceptance/rejection of the colour of sunglasses originates from what the observer sees rather than from what the glass looks like, in other words that it is not the colour of the lens which is the basic parameter for the comfort of the wearer, but the colour of the environment as perceived through the lens. Therefore, while the manufacturer controls the spectral optical density of the glass, we look for a rating index that establishes the relationship between the spectral characteristics of the glass and the visual percept. As practically almost all the field of view of an individual wearing spectacles is subject to light filtering, the situation is very much like substituting a coloured light source for the natural light source.

In this study, we have developed a model for rating colour distortions produced by filtering light. Then, we have applied the model to a collection of real tinted ophthalmic lenses. At the end, we compare the objective colour distortion index with the acceptance/rejection judgement of observers.

2. MODELLING COLOUR ACCEPTANCE

The starting point of the model is the assumption that the observer judges the colour appearance of the panorama rather than the colour of the glass itself. Practically, wearing colour spectacles introduces colour modification of all the objects of the panorama. The phenomenon of chromatic adaptation compensates for most of the colour change. However, there are some residual distortions which are responsible for the degradation of the global colour appearance. Therefore, a method which accounts for chromatic adaptation and which allows estimation of residual distortions, such as the method to calculate the colour rendering index for light sources, should be suitable.

The method to calculate the colour rendering index establishes a relationship between a test source, a reference illuminant and a collection of colour surfaces. Illuminants are defined by their spectral power distribution (SPD) of energy. Samples are defined by their spectral reflectance. As suggested by CIE TC 1-33[1], we consider three illuminants: the test illuminant that corresponds to daylight as filtered by the tinted lens, a target illuminant that corresponds to daylight without filter, and the reference illuminant that corresponds to D65. Therefore, the colour specification of a sample is calculated using the filtered daylight and the unfiltered daylight, and these two colour specifications are transformed to the standard D65 based colour space.

Strictly, the target illuminant chromaticity should be near to the filtered test illuminant chromaticity leading to the possibility of calculating the correlated colour temperature for the test illuminant. However, in the case of tinted lenses, the colour of the illumination can change considerably, so we have to admit that the correction for chromatic adaptation proposed by TC 1-33 is still valid for large colour differences between the test illuminant and the target illuminant. Finally, for the sake of simplification, we assume that natural daylight is well described by D65.

The next step of modelling consists of choosing a data basis for representing the colour objects of the surrounding. In the absence of the spectral record of every surface included in the field of view of the observer, we have chosen a collection of spectral reflectance functions of coloured surfaces that are representative of real surfaces. The Munsell atlas collection comprehensively represents the hue, lightness and saturation gamut of colours that can be experienced by an observer. Although every sample is only defined by its colorimetric specification, spectral reflectance functions of one collection have been published and are available on the Internet[2].

Figure 1 illustrates the method that we use.

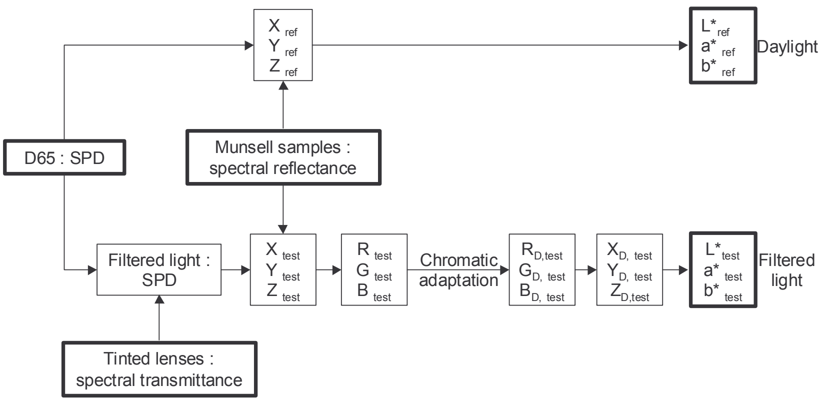

Figure 1. Schematic diagram of the model for predicting the acceptance of tinted ophthalmic lenses.

The last step of modelling consists of applying a chromatic adaptation transform to eliminate the overall colour change that the visual system compensates. We choose the chromatic adaptation transform that was introduced by CIE[3] in 1994. There, tristimulus values XYZ of every sample and of the test light source are first linearly transformed into RGB quantities analogous to cone responses. Then RGB quantities are adjusted to R_D G_D B_D equivalent quantities for D65 illumination using non linear relationships with empirically determined parameters which are similar for the R and G cone like signals and different for the B cone like signal. Finally, the R_D G_D B_D quantities adjusted for chromatic adaptation are reverse transformed to X_D Y_D Z_D tristimulus values. For the calculation, the illumination is supposed to be at 1000 lux and the background reflection factor at 0.20, as proposed by CIE TC 1-33.

All colour specifications are represented in CIELAB space using D65 as the neutral illuminant. For every sample, the colour distortion is graphically represented in the a* b* chromaticity diagram by a vector that originates at the colour of the sample seen under daylight and ends at the colour of the sample as seen through the tinted lens by a chromatically adapted observer. Graphically, all colour distortions are represented by a field of vectors [4].

Although the Munsell basis comprises 1269 sample spectral reflectance functions, a selection of one out of ten samples has been used for the graphical representation and for the statistics. Once all colour distortions for a collection of samples have been calculated, a statistical index can be derived, either from averaging the amplitude of the colour deviation vectors, or from calculating the standard deviation of the angle of the colour deviation vectors.

3. APPLICATION OF THE MODEL TO A SET OF REAL TINTED OPHTHALMIC LENSES

Using the method described in the previous section, the field of vectors representing the residual colour distortions after adjustment for chromatic adaptation has been drawn for every real tinted ophthalmic lens. Figure 3 shows the field of vectors in the *a* b** chromaticity diagram for two tinted ophthalmic lenses.
Lens "D" is a green coloured lens to which observers easily adapt. Indeed, it only very little distorts the colour of the world. We can see that the chromaticity distortions are only about a few CIELAB units.
Lens "C" is also a green coloured lens but it originates from a different manufacturing process. It is often rejected by the wearer. Even though our model takes into account the chromatic adaptation, colours are severely distorted, up to about thirty CIELAB units. Moreover, the overall colour gamut is reduced and compressed along the *b** axis which means that while small colour differences that are based on red-green discrimination (*a** axis) remain visible, colours that are different along the blue-yellow dimension (*b** axis) might not be discriminated any more by the wearer.

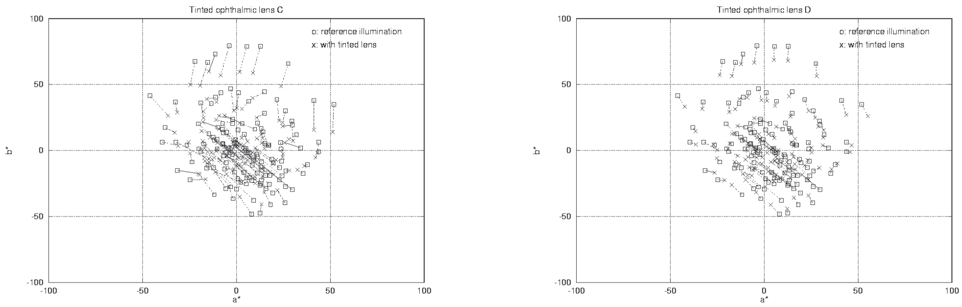

Figure 3. Colour distortion vectors for two tinted ophthalmic glasses in the *a* b** chromaticity diagram.

So the comparison between the two lenses shows that lens "C" produces greater distortions than lens "D". Nevertheless, distortions follow a regular pattern.

Lens "E" is a blue coloured lens that has been developed and promoted for bicycle riders. Figure 4 shows that lens "E" not only produces large colour differences but also destroys colour classification. In the *a* b** chromaticity diagram, the vector magnitudes are up to about thirty CIELAB units. Further, the vector field looks disorganised. There is no uniform pattern of colour change. Some colour specifications are displaced in any direction, even for samples that are nearby when seen under daylight illumination.

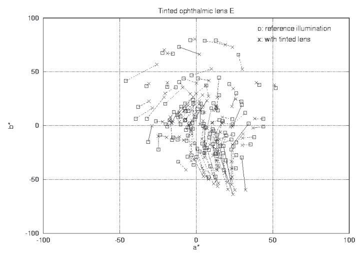

Figure 4. Colour distortion vectors for tinted ophthalmic lens "E" in the *a* b** chromaticity diagram.

Two statistical indices "Norm" and "Disorder" have been calculated, refering to the module or to the angle of the vectors respectively (table I).

Table I. Statistical indices derived from the field of vector for 3 tinted lenses "D", "C" and "E" (Disorder = standard deviation of the angle of 127 vectors, in degrees).

Lens	Norm	Disorder
D	6.53	31.958
C	12.74	36.309
E	13.33	40.246

4. DISCUSSION

In the previous sections , we have shown that it is possible to represent in the CIELAB system, the colour distorsions produced by a tinted ophthalmic lens for a chromatically adapted observer.

Preliminary experiments have been performed with real observers in order to validate the colour distortion graphs. Thirty-two observers were asked to express their preference about the ophtalmic lenses, on the presentation of a photograph that represents natural surrounds (mountains). The experimental procedure is a two-alternative forced-choice procedure. At each trial, two filters are handled in succession in front of the projector, so that the observer has to choose the one he prefers when viewing the same image. Several tinted ophthalmic lenses have been proposed. Every possible pair of filters is presented to the observer during one session.

The aim of the experiment was to verify that the objective method of rating a tinted ophthalmic lens could predict the subjective judgement given by wearers. Actually, lens "D" has been ranked before lens "C" by 28 observers out of 32. Lens "E" has been ranked the last by 30 observers out of 32. Examination of the field of vectors plotted for each lens can explain the classification. For instance, lens "D" yields smaller distortions than lens "C", and the field of vector plotted for lens "E" shows a large amount of disorder. So results show a satisfying agreement between the subjective rating and the statistical index including the amplitude and the variability of the orientation of the distortion.

5. CONCLUSION

In conclusion, it seems possible to predict the rejection/acceptance judgment of observers about tinted ophthalmic lenses using a model, mostly based on a colour rendering scheme. In particular, the calculation of a statistical index has allowed to discriminate and classify two lenses that were originally aimed at the same colour but had been manufactured along different chemical processes. Already available, the calculation of the statistical index and the distortion plot could help the supplier to improve the manufacturing of coloured ophthalmic lenses. Indeed, this provides a rational and scientific method of design for tinted ophthalmic lenses, dedicated to the optimisation of the visual perception of the wearer, and making obsolete the usual subjective and disputable character of a colour choice exclusively based on persons preference.

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